KNOWLEDGE SHARING AND KNOWLEDGE MATURATION IN CIRCLES OF TRUST: THE CASE OF NEW PRODUCT DEVELOPMENT

Completed Research Paper

Valéry Merminod
University of Grenoble (CERAG) and Skema
Valery.merminod@upmf-grenoble.fr

Frantz Rowe
University of Nantes (LEMNA) and Skema
Frantz.rowe@univ-nantes.fr

Dov Te'eni
Tel Aviv University
teeni@post.tau.ac.il

Abstract

This paper is about knowledge sharing and maturation in new product development (NPD). We show how knowledge items mature as they are shared in expanding circles of trust until the items are exhausted and transformed to new knowledge items to serve new activities. Our conceptual framework integrates knowledge sharing, circles of trust and knowledge maturation. We explore knowledge maturation patterns through six in-depth case studies of NPD projects using Product Lifecycle Management (PLM) technology. Our results show that knowledge maturation patterns are contextual and complex. Knowledge is shared in circles of trust, where one circle feeds into another during the maturation process. Psychological safety plays a role in the choice of circles of trust for knowledge maturation. These results suggest that formal NPD process and progress across circles of trust interact and reinforce knowledge transformation. These results have implications for articulating the IT architecture for NPD.

Keywords: New Product Development, knowledge maturation, circles of trust, product development stages, PLM.

Introduction

This research is about knowledge maturation as it is seen from an organizational perspective. We argue below that knowledge maturation is related tightly to knowledge sharing among the collaborating agents in the organization, but this relationship is complex. We find it difficult to talk about knowledge as a unified construct that develops linearly from nascent to mature. Instead, we examine knowledge maturation as many proximate processes, each proximate maturation process designed to support specific organizational goals managed by different agents who must share knowledge to advance their goals. Knowledge sharing occurs through multiple networks: within teams and across teams, each network characterized by different knowledge sharing goals and outcomes(Hansen et al. 2005). We concentrate on one aspect of networks that affect knowledge sharing, namely, the use of trusted networks and claim it is essential for knowledge maturation. Although we do not examine trust directly, we look at the trusted networks that people choose for creating, sharing and discussing their knowledge; these are their circles of trust. The role of trust in deciding whether and how to share knowledge will be used to explain why people share knowledge in one circle rather than in another.

We conceptualize this interplay between knowledge maturation and knowledge sharing in the context of new product development (NPD), which is a knowledge intensive environment that relies on co-creating and sharing knowledge amongst designers and managers from various departments. Furthermore, NPD is usually organized by breaking down the work into manageable work goals and determining what knowledge is needed to complete the goal. In other words, in NPD, knowledge is created or refined as the product is developed. Thus there are two timelines involved: one is the product development time line, from conception to a working product, and the other is the knowledge maturation time line. Aligning knowledge maturation with product development is a source of difficulty as we explain below. Moreover, knowledge sharing is further complicated by the diversity of agents, goals and perspectives, which also complicates knowledge maturation.

Theoretical background

Knowledge matures by processes of creating and sharing representations within circles of trust. We first discuss knowledge maturation and then examine the barriers to sharing knowledge which are fundamentally tied to psychological safety and circles of trust.

Knowledge maturation

We see organizational knowledge as a web of interrelated understandings of parts of organizational reality (or contrived reality) at some point of time under certain conditions. Thus it is a notion of fragmentary, tentative and evolving, and loosely linked understandings that comprise organizational knowledge (Boland et al. 1994). We therefore chose to view knowledge maturation pragmatically as an ensemble of many proximate maturation processes, each maturing from one understanding to another in the local context of applying the knowledge to achieve particular work goal.

Central to knowledge intensive environments is the notion of knowledge representations (Boland et al. 1994). Rich representations of organizational phenomena are essential for effective individual self-reflection, dialog and action. Representations reside in the minds of people or are explicated, in part, as artifacts such as models, documents and software; we view these types of representations as two dimensions on which knowledge develops in parallel: mind and artifact. Research on cognition in design - an essential aspect of NPD- sheds light on the processes involved in knowledge generation and refinement. Berente, Baxter and Lyytinen (2010) examine the processes of change (iterations) in mind and artifact representations that lead to new knowledge. In the mind of the designer, representations change by 'generate-test cycles' (Simon, 1996). Designers act as satisfiers, adopting a temporary working solution so that they can progress in their design work. The designer generates a new solution when he or she learns more about the prevailing context and realizes the old solution is no longer appropriate. Whilst this view of cognition may explain an individual's process of knowledge creation, it must be augmented to reflect team work and socially constructed knowledge typical of new product development. Knowledge

maturation is a dynamic process of enrichment and validation of knowledge. Knowledge maturity can be considered to be intuitive although elusive, in that it may at some point appear to be mature, but then in light of new knowledge, new circumstances and goals, and new or changing knowledge beholders, seem to be immature again. We therefore look at local, proximate processes of knowledge maturation that are designed to reach a level of maturity sufficient for solving the immediate work goal.

It is easier to define and measure the maturity of explicit knowledge, the aspect on which this paper focuses, although we hasten to note that the explicit-tacit cycle (Nonaka et al. 1995) itself is part of knowledge maturation. In practice, the maturity of knowledge often evolves from drafts to deliverables during the design process. Preliminary knowledge comprises sketches of ideas; whether visual or verbal, they are general and often open to different interpretations because of their low specificity. As details are added, more complete and contextualized representations emerge, which add dimensions, levels of representation, concrete examples, descriptions of functionalities and form, answers to questions and uncertainties, and consequently more confidence in the idea. More mature knowledge may add other aspects, such as the larger picture, interfaces with other ideas and perhaps even conflicting ideas, which are especially relevant when going beyond a specific proximate process of knowledge development to a higher level analysis of knowledge.

Knowledge further matures when the individual shares representations, usually artifacts, in order to subject them to additional testing by others often holding different representations (different perspectives). Winograd and Flores (1986) describe this activity as a hermeneutic circle in which individuals understand each other better and refine their representations in light of their critical dialog. For the hermeneutic circle to be effective, the individuals in dialog must hold initially different representations (otherwise knowledge refinement will be minimal) (Winograd et al. 1986). On the other hand, too divergent representations will hinder communication and hinder the possibility of mutual understanding (Te'eni 2001). The benefit and risk of different representations are therefore important in choosing with whom to share knowledge.

The major paradox with knowledge maturation is that it requires sharing, but only mature knowledge is usually shared. This is because less mature knowledge is more ambiguous, open to misunderstanding but also to misuse. Less mature knowledge is also tied to earlier stages of product development, thus opening the actor disclosing the information to a higher risk of economic costs of greater competition. Less mature knowledge is less edited and less rehearsed, and it also stands a higher risk of embarrassing the person sharing the knowledge. Maturity is similar to the degree of message formality which has been shown to affect communication (Te'eni, 2001).

Knowledge maturation is determined by the applicability of the knowledge to work goals. In NPD, the work goals are tied to the product life cycle, which dictates the knowledge needed at each stage. We therefore explore knowledge maturation in the context of the product life cycle, concentrating on the earlier stages of product development, where the creation and sharing of knowledge are intensive.

The NPD process is organized around stage gates, and these stages determine the immediate work goals for which knowledge is created and applied. The stage gate approach corresponds to a product life cycle with new information added as the product progresses, existing knowledge is refined and specified, and old information is discarded after use. The representation of knowledge, particularly explicit knowledge managed in predefined templates, is designed to fit, and serve, the planned progress of product from conception to delivery. The 'stage gate approach' (Cooper 2008) emphasizes the sequential dependency of a stage on its preceding stages. This dependency is reflected by the prerequisite information of one stage on the information generated in previous stages. It is the most frequently applied approach in industrial firms and classically encompasses five stages: scoping, build business case, development, testing & validation and launch. In the case of incremental product innovation for home-care appliances, the stage gate approach has been rather beneficial (Merminod et al. 2008), while in IS a four stage communication process between users and software developers has been found critical to effective outcomes (Gallivan et al. 2003). However, depending on project complexity (Sosa et al. 2002) and type of service or product to be developed (Sheramata 2000), these formal and standardized approaches may be ineffective (Dougherty 2004), and may be correlated with learning failures, which in turn lead to new product failures (Sethi et al. 2008). This may be related to the fact that in NPD knowledge maturation does not completely follow the NPD process as defined by the stage gate approach. Our central hypothesis is that while the five-stage life product life cycle is the context for knowledge maturation, the two timelines are

not correlated linearly. Within the constraints of the product life cycle, multiple proximate maturation processes develop, each proximate process is usually associated with one or two stages in the product life cycle and each building on its predecessors. With the concept of circles of trust expanded below, we try to identify some knowledge maturation patterns in the NPD process.

Barriers to knowledge sharing and circles of trust in New Product Development (NPD)

Past research has reported time and again the reluctance of actors in organizations to share their knowledge and the information they come to hold (Coakes et al. 2008). The cost of sharing knowledge can be economic and political, e.g., losing a competitive advantage in a newly invented product, losing a market share by revealing knowledge of potential customers, losing a power position within the organization by losing ownership on a certain expertise and many others. The cost to the actor can also be social. One of the key explanations for not sharing knowledge is related to psychological safety. Psychological safety describes the perception that employees feel comfortable to express themselves (Edmondson 1999) and "…to show and employ one's self without fear of negative consequences to self-image, status or career" (Kahn 1990, p. 708). It concerns an environment in which interpersonal risk taking is encouraged. Employees are particularly sensitive to their team members' evaluations and responses to their own actions. Thus, when employees feel that they are not psychologically safe, they are less likely to express opinions openly and share knowledge. If an employee senses that he may be punished or ridiculed for sharing knowledge, or if he does not feel confident that the knowledge will be positively accepted by peers, the employee will be inclined not to share. "Team psychological safety involves but goes beyond interpersonal trust; it describes a team climate characterized by interpersonal trust and mutual respect in which people are comfortable about themselves" Edmondson (1999).

Knowledge grows through individual self-reflection and through dialog amongst people. We thus envisage expanding circles of reflection and dialog that can be characterized by a level of trust between the individual and the others belonging to the particular circle. In sociology and psychology, trust has been defined as an individual's confidence in others' intentions and motives (Mellinger 1956). In management, trust has been defined as confident positive expectations regarding the other's conduct, which are defined as a propensity to attribute virtuous intentions to others and a willingness to act on the basis of another's conduct (Lewicki et al. 1998). Trust is tightly connected to communication and knowledge sharing (Staples et al. 2008). It can be seen as the common ground arising from past interactions, which facilitates more efficient communication with fewer problems and effective social connections, team spirit and shared project goals. In this paper, circles of trust are defined by the type and scope of communication. The closer circles represent higher levels of trust in people feeling more comfortable and confident in communicating and sharing knowledge; the more remote circles represent a lower level of trust in which people are less comfortable, less confident and often less willing to share knowledge. In an organizational setting, circles of trust are a mixture of design and choice. Organizational structure dictates formal networks for communication and reporting, e.g., laterally within teams or departments and up and down chains of command. On the other hand, actors choose to trust certain colleagues and not others and act out their choices by adapting formal channels or creating new informal networks.

From the perspective of a project member working in NPD, we can define four circles of trust in which members reflect and communicate: personal, interpersonal, project and organization(Blanco et al. 2007; Merminod et al. 2008).

- Personal: First, actors produce their initial ideas and solutions based on available information and on their own knowledge and competencies. This knowledge can be arranged in draft objects which are kept in their personal circles of trust, also called private (Blanco et al. 2007).
- Interpersonal: In this step, interactions consist of a proximity circle of trust based on personal networks and trusted relationships(Blanco et al. 2007). Actors need to confront their ideas with other actors' trusted colleagues in order to get their points of view. The actors may belong to the official project team or not. This circle of trust is an ideal place for informal confrontation and advice.
- Project: When the argumentation is coherent and when the knowledge is considered readily applicable, it is then shared outside the personal network (Blanco et al., 2007). Actors share the

knowledge by publishing it in the project circle of trust. Knowledge shared at the project level is not officially validated but sufficiently convincing to be published. A group member trusts the group when he believes other members of the group attempt to honor their commitments, are honest and do not take advantage of one another (Cummings et al. 1996).

- Organization: Finally, when the knowledge is formally validated at project level, all stakeholders associated with NPD should have access to knowledge; knowledge is thus shared at the organizational level. This is the most outer circle of trust. Even if taken off public access, it always stands the chance of being recorded and preserved somewhere beyond control. Knowledge is published, assuming that untrustworthy people may use it too.

Methodology

Study design and focus of analysis

Due to the limited amount of research dedicated to knowledge maturation, the purpose of this research is theory building to improve the conceptual understanding of this phenomenon. The qualitative analysis is structured around six embedded case studies of NPD projects carried out in one organization. The design of this research is grounded on a longitudinal real time approach (Eisenhardt et al. 2007; Leonard-Barton 1990) in order to deeply understand the context, as well as the social and political interactions between actors.

The context of the case is a business unit dedicated to Linen Care products of a small domestic appliance company. This unit is characterized by a design process with complex product architecture and the increasing outsourcing of finished product key components to suppliers. The choice of projects is mainly based on the representativeness of technical diversity in projects with three types of projects: radically new products, new product architecture and product renewal (Wheelwright et al. 1992).

In this case study, our unit of analysis is the knowledge object. The analysis is focused on two knowledge objects from NPD projects: the marketing and the technical specifications which are two critical objects, especially during the design phase of the project. The marketing specifications contain all requirements concerning the functionalities, the market and marketing positioning of the future product. The technical specifications contain all requirements such as technical constraints, targeted product cost revenue and first 2D drawing.

Research site and project sampling

The case is situated in a French industrial group for small domestic appliances with international brands. The external environment of this group is characterized by strong competition from no name products, pressure from large retailers, and important changes in consumer behavior (decrease of middle range products, increase of low cost and high quality products). This group is known for its ability to continuously create new concepts and products. This dynamic of innovation is crucial for maintaining its lead over the competition. The company employs 510 R&D and product development people in six countries. In NPD, project teams include around ten people and have similar project duration.

The NPD process of the business unit is supported by an IT solution: a Product Lifecycle Management (PLM) solution which supports project, product and process knowledge objects collection and circulation. In parallel, other digital solutions involve use of emails, hard drive or some communication solutions.

PLM promises to manage new product development project information using object storage and workflows to numerous functions in the firm in addition to R&D itself, such as logistics, marketing, manufacturing and accounting (Batenburg et al. 2004). In sum, PLM integrates product design knowledge in a single logical database, and similar to an ERP, allows its use by several functions of the firm. PLM supports the development phase from design to manufacturing (Batenburg et al. 2004). PLM technology historically comes from Product Data Management (PDM) systems (Grieves 2006; Stark 2004). PLM sub-systems cover a wide range of functionalities from the three New Product Development systems identified by Pavlou and El Sawy (2006): Organizational memory systems (OMS),

Project/Resource Management Systems (PRMS) and Cooperative Work Systems (CWS) (Merminod et al. 2011).PLM features such as creation of visualized boundary objects, common knowledge repository, sequential workflow coordination and dashboards for monitoring are some of available functionalities to support NPD process.

The industrial group decided to implement a PLM solution in 2004. The main objective was to replace heterogeneous IT solutions with an integrated solution which supports the product, project and NPD process: PLM. The PLM solution is TeamCenter Engineering from Siemens.

Yin (2003) suggests that when investigating phenomena for which we have little or no theoretical background, the researcher may select an exemplary case that provides the best example of a phenomenon. The cases selected in this paper meet this criterion. The Minute Iron project (a radically new product) includes technical novelties, such as a quick warm up functionality of the iron. This project is considered to be strategic by marketing teams because there is a real need for quick warm irons, and existing offers do not really propose adequate solutions. This project was categorized as radically new for the business unit. For Pressing power steam generator (a renewal product), technically, there is no novelty for this evolution of the existing steam generator, but some components are replaced and there has been a change of some suppliers in charge of providing components. This project is considered as product renewal for the business unit. The Pro minute steam generator (new product architecture) is considered to be strategic by marketing and business unit management. Technically, this project relies on new product architecture.

We have focused only on the preliminary design phases of NPD process: the scoping and build business case stage gates because these phases enable to build design options critical for the development of the future products. The marketing and the technical specifications were also selected because the small domestic appliances industry is organized around a market pull approach where the initial input for NPD project is the marketing specifications which are generated by the marketing team. Based on these marketing requirements, the technical specifications constitute the detailed technical requirements for the future product variants of the project. Sociologists of industrial innovations have conceptualized artifacts, such as these specifications, as intermediary objects because they evolve and constitute a provisory mediation for the understanding of the final product (Vinck et al. 2003).

Data collection, coding and analysis

Data collection

Between September 2005 and September 2008, one of the authors was in the company on a daily basis, and was positioned at the headquarters level in order to observe NPD projects involving suppliers. In particular, we observed in detail the three projects during one year in order to better understand knowledge maturation patterns in circles of trust. Data collection consisted of a combination of interviews, documentation, observations and artifacts. We conducted 15 interviews, including 12 recorded semi-structured interviews totally transcribed by project members involved in NPD projects. We collected most of object maturation, thanks to access to IT databases such as emails and PLM solution. Moreover, the authors observed a part of these NPD projects maturation processes and took field notes. This diversity of data collection enabled us to triangulate (Yin 2003) using different sources of data (Table 1).

Table 1: Data collection

Interviews	*Collective*	3 with project team members from the 3 selected projects
	Individuals recorded	12 (3 project leaders, 3 marketing leaders, 3 design technicians, 2 quality managers, 1 industrial manager)
Secondary data	*Documents*	All documents were available: mails, specifications, etc.
Observation	*Field notes*	Field notes and participation in choices in implementation rules in PLM

Data coding and analysis

The data coding is based on the operationalization of the circle of trust and object maturation(Table 2).The qualitative analysis is based on the analysis of the evolution of the two intermediary objects chosen so as to observe maturation (marketing and technical specifications) and the support for object sharing (the use of IT solutions). In particular, we observe the maturation process within the bounds of what we call a proximate maturation process, which for the two chosen specifications (intermediate objects) occurs during the scoping and build business case stages. We also conducted detailed interviews analysis through Nvivo. In the following we also use the designation of levels in the PLM systems to reflect circles of trust

The nature of circle of trust is analyzed through the level of trust to share knowledge. Operationally, we distinguish four circles of trust (Table 2):

- Personal: initial ideas which remain personal in the sense that they are not shared,
- Inter personal: first sharing of drafts with personal network and trusted relations
- Project: shared objects are available for all project members
- Organization: objects are available for a large number of organization stakeholders.

The level of knowledge maturation is analyzed through object completeness and level of accuracy of object content. Operationally, the analysis of object maturation path is performed through object status change which is managed during the NPD process. We have distinguished four different maturation levels (Table 2):

- A Draft object correspond to the state of the object when the owner defines initial content, ideas or hypothesis for a project problem or solution
- An Exhibit object is associated to a conveyance modality where the owner aims at convincing about the existence of a problem or at showing a solution
- An Enabled object corresponds to the moment where the content is close to validation, the object is nearly completed. The object owner accepts to diffuse to others even if the content is not officially validated but sufficiently convincing to be published.
- A Deliverable object corresponds to an officially verified and validated object.

For data analysis, we have tracked the evolution of two key objects: marketing and technical specifications in the three selected projects.

Table 2: Data coding matrix

Dimensions	Proxy	Definition	Measure
Circles of trust	Personal	Object is not shared	No sharing with other colleagues
			Storage on hard drive
	Inter Personal	Object is shared with personal network and trusted relations	Object sharing with a limited defined number of colleagues
			Restriction of object display
			Exchanges by email or by PLM
	Project	Object is shared with all project members	Object sharing with all colleagues
			Display for all project members
			Storage on PLM solution
	Organization	Object is shared with a large number of organization stakeholders	Object display for a large public
Maturation of object (Status of the object)	Draft	Object containts initial ideas	Completeness: most of object fields are empty
			Accuracy: information collected is not validated
	Exhibit	Object is in progress	Completeness: more than half of object fields are fulfilled
			Accuracy: most fields are not yet validated
	Enabled	Object is close to completion	Completeness: more than half of field content is fulfilled
			Accuracy: most fields are validated
	Deliverable	Object is validated	Completeness: fields are fully fulfilled
			Accuracy: all content is validated

Results

First, we analyze object maturation patterns of marketing and technical specifications, and then we analyze interactions between object maturation through the combination of marketing and technical specifications.

Marketing specifications maturation

The owner of marketing specifications is the product leader from the marketing team. The marketing specifications comprise the preliminary input information for the project.

Within case analysis

In the Minute Iron project (radically new), the marketing leader had six years of experience within the business unit. She was not very close to the technical and manufacturing teams, considering there were clear differences between the marketing and engineering approach, requirements and constraints.

> "Marketing and engineering teams do not have the same way to work. Market environment is always changing and engineering teams have difficulties to accept several specification modifications in the beginning of the project. This is why I share a first specification draft and I wait the most I can before putting a validated version" (Marketing leader, Minute Iron)

The uncertainty of new functionalities of the steam iron generated some difficulties during the preliminary phase of the project. In other words, the marketing leader had given only very generic, imprecise information to the project leader, which raised some conflicts because the engineering team could not start working on the product's general design and CAD representation with such general product specifications, as indicated by the project leader Minute Iron).

> "I had difficulties at the beginning of the project with the marketing leader because the schedule of the project was short but the first functional specifications were too general, not enough precise to start working on technical design" (Project leader Minute Iron).

The marketing leader made modifications on functional specifications to scoping gate while exchanging directly with the marketing team and project manager, but this was outside the project circle of trust supported by PLM solution. She exchanged emails instead of using the PLM institutional project solution. Functional specification was collected in PLM only for scoping milestone but not earlier. Then, evolutions

on functional specifications were made outside of PLM by emails exchanges mostly till build business case milestone.

In the pressing power Steam Iron project (renewal), the marketing leader was new in the company (one year of experience), and did not know the technical team members from viewpoint of quality, standards and industrialization especially. Moreover, she was not really self-confident in managing meetings with other project members mainly coming from technical fields. The technical team was experienced and, in contrast to the marketing leader, the team already had some common experience on previous NPD projects.

The marketing leader wanted to keep control on the diffusion of the functional specifications while systematically exchanging in one-to-one mode with project members such as the sales or project leader. Marketing specifications were shared at the project level through PLM system only for the scoping gate and not during the building of the business case phase.

In pro minute Steam Iron project (new architecture), the marketing leader was in the company for more than 15 years, and thus he knew most of the team members quite well. He was less reluctant to share marketing specifications even if the content was less accurate and complete, or even if there was a risk of criticisms from the technical team.

There were several iterations between the marketing leader and the marketing team before sharing the first draft of marketing specifications with the project manager.

> "Honestly, at the beginning of the project, I have tried to keep control on marketing specifications so I limited exchange with marketing department and with the project leader" (Marketing leader pro minute).

The marketing leader decided to change some product characteristics after the scoping gate, but he did not share at the project level. He had some face-to-face interactions with style and project managers, as well as email exchanges with colleagues from the marketing and sales department. Consequently, the marketing specification tracking was partially done in PLM and the number of marketing specification versions in PLM was limited to three.

Stylized case

The marketing leader wanted to keep control of the object while sharing marketing specifications with a very limited number of trusted colleagues to ensure a very tight control on the object and centralization of the coordination of the diffusion of the object. She tried to share the object at the project level as late as possible. This generated knowledge asymmetry with other project members. Operationally, she communicated mostly outside the IT project solution (PLM) by emails or face-to-face in order to manage the diffusion of the object during the scoping and building business case phases. We investigated email flows to understand more about the interactions and mutual adjustments that took place in the interpersonal circle of trust. We observed a great number of emails generated between the marketing leaders and marketing team, the project leader and other team members. Such exchanges concerned mutual adjustment and annotations in order to reflect actor interactions in inter personal circle of trust (Figure 1) for draft and exhibit marketing specifications.

Moreover, the marketing specifications were shared at the project circle of trust at the end of the scoping stage because it was mandatory in project group rules when marketing specifications were in enabled status. But just after this stage gate, the marketing leader came back to the interpersonal circle of trust in order to manage the evolution of the object in enabled status: close to completion (Figure 1).

The marketing specification maturation process is based on proximate interactions between marketing members when object is drafted. Then, marketing specification is shared with other project members when object is more mature (Figure 1).

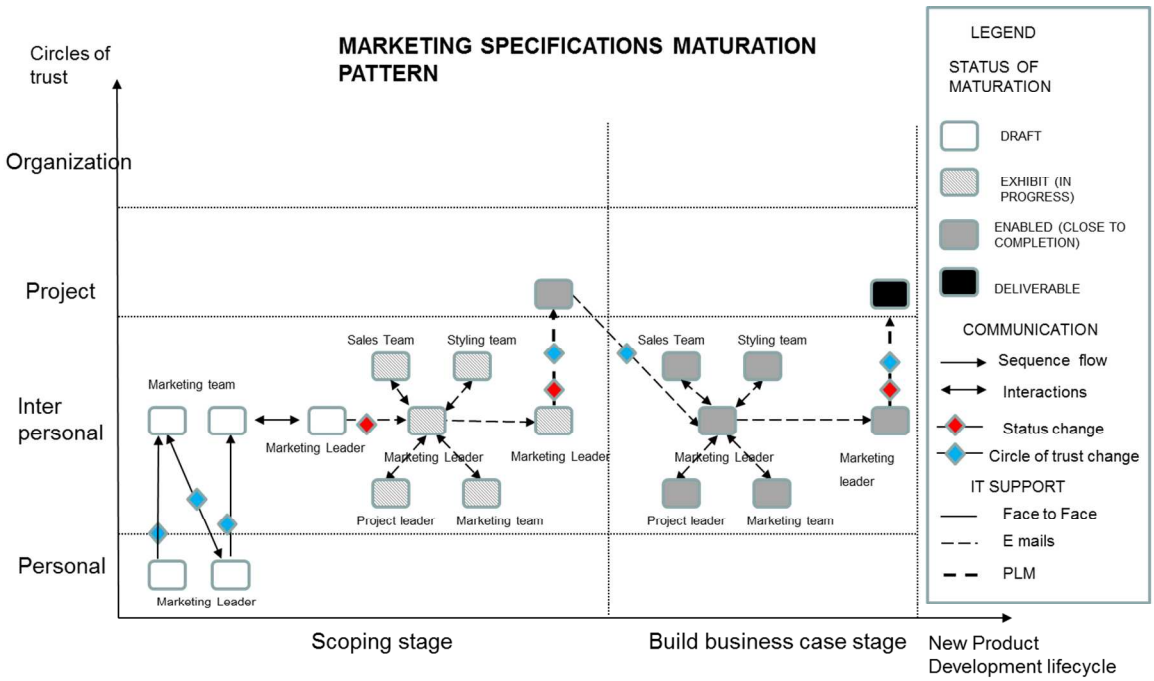

Figure 1: Marketing specifications maturation (stylized situation from the three selected projects)

Technical specifications maturation

The owner of technical specifications was the project leader who was an engineer from the engineering department. Technical specifications were based on marketing specifications provided by the marketing leader.

Within case analysis

In the Minute Iron project (radically new), the project leader was experienced (12 years as project leader), since he had already worked with all project members of the quality, manufacturing or engineering teams. He was considered to be a charismatic leader by other project members who felt confident working with him. At the first draft of technical specifications there were some iterations between the project leader and engineering team before sharing at the project level because there was a technical constraint which was potentially unfeasible, and hence the need to check the point before continuing the project. There were some exchanges of emails at the beginning of the scoping phase in order to manage relations between the marketing and project leaders.

> "At the beginning of the project, there was an uncertainty concerning the soleplate to use in order to manage the marketing constraints from marketing teams. I had to validate some technical options with my colleagues before sharing the technical specifications with other team members" (Project leader Minute Iron).

Quickly, technical specifications were shared in PLM and object modifications were accessible for all project members in exhibit status. The technical specification evolution tracking was ensured through PLM with numerous versions and evolution from exhibit to enabled and validated status in PLM.

In pressing power Steam Iron (renewal), the project leader in charge of technical specifications was on the engineering team for seven years. He had an operational role for renewing the existing range of steam irons. There were some exchanges with the engineering team for validation of key technical options before sharing at the project level. The marketing specifications were shared by the PLM system from the first draft of technical specifications. So, all technical specifications modifications were accessible through PLM with a complete audit trail.

In the pro minute Steam Iron project (new architecture), the project leader was the youngest project leader within the business unit (four years of experience within the company). The first drafts of technical specifications were initiated by the project leader, but the work was collective in the engineering department in order to define the content of technical specifications. The project leader had a coordination role more than an operational role for building technical requirements.

> "… on this project, some components of the steam iron were new so there were many iterations with engineers, technicians and standard manager in order to validate options or find solutions for managing interfaces between components" (Quality manager Pro minute).

The project leader forced himself to systematically use the project official IT system: PLM in order to be as transparent as possible in the sharing of technical specifications.

Stylized case

At the beginning of the scoping phase, the project leader quickly shared technical specification drafts with a limited number of trusted colleagues from the design department. He then shared the object with all project members at the project level in order to take into account the constraints on the project as soon as possible (Figure 2). In order to share and broadcast the evolution of objects to all project members, the project leader used PLM to support object sharing at the project level. The coordination strategy for technical specifications sharing was clearly multipoint flow in order to take into account reciprocal constraints as soon as possible. Thus, knowledge asymmetry between project members was limited in comparison with marketing specifications. In the three selected projects, the object sharing was open and based on direct mutual interactions between project members without a pivot role from the project leader. The marketing specifications were shared at the project level early in the NPD process through PLM solutions. There was limited use of emails for maturation of technical specifications. The use of the institutional project solution, such as PLM, in order to support technical specifications sharing is characteristic. The technical specifications are shared between different project members from the beginning of its creation based on numerous proximate interactions (Figure 2).

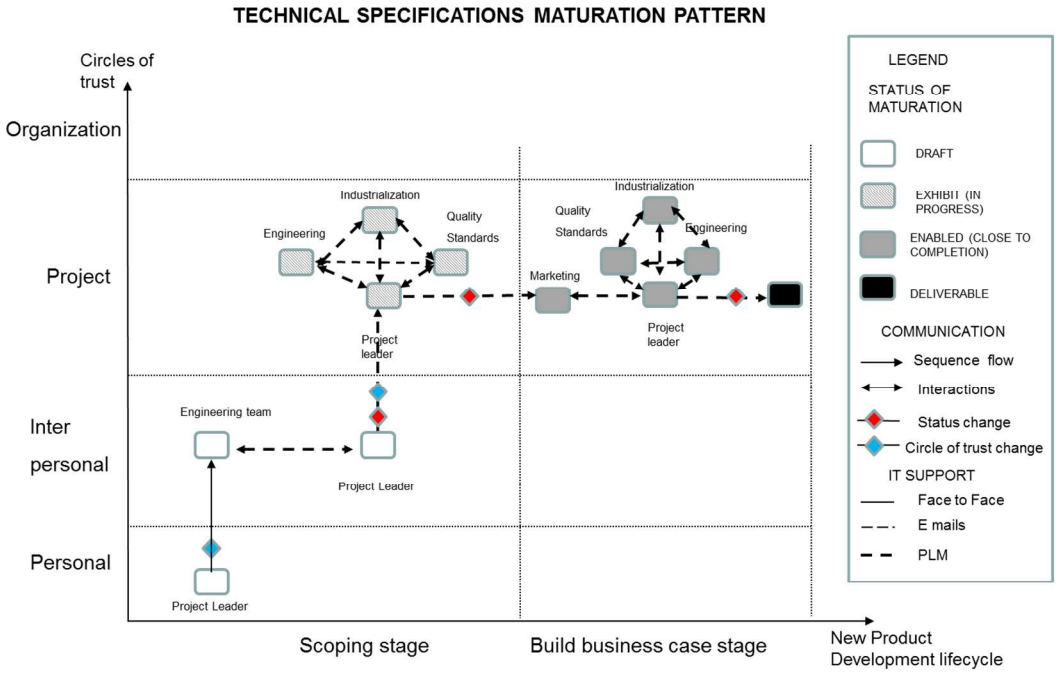

Figure 2: Technical specifications maturation (stylized situation from the 3 selected projects)

Interactions between objects: impact on maturation

We analyzed interrelations between marketing and technical specifications during the first stages of the NPD process. The marketing specifications were the initial input of the NPD process. This object was shared with a minimum number of project members at the beginning of the project. Thus, technical specifications could start only when the first draft of marketing specifications was communicated to the project leader.

Differences between marketing and technical specifications maturation patterns

In the Minute Iron project, the initial sharing of marketing specifications between project members was difficult, which raised some pressure on the project. The marketing specifications were shared quite late in the scoping phase. So, to try to reduce the delay on this first NPD phase, the technical specifications were shared very early, even if it was a first draft. It generated numerous technical specifications versions in PLM system whereas marketing specification were managed outside of the IT system through emails essentially. Draft and exhibit marketing specifications were not stored in PLM system, whereas technical specifications evolution is easily available by tracking in PLM.

In the Pressing Power Steam Iron project, the exchanges of marketing specifications were limited to a restricted number of people during the scoping phase. The marketing leader had very tight control on marketing specifications due to its limited experience and limited trust in other team members (no previous common experience).

> "During the first steps of the project, I manage and decide when I share the marketing specification and for which part of the specification content" (Marketing leader Steam Generator renewal).

The project leader had to compensate for the lack of information provided by marketing leader. He had to take technical options without information and feedbacks from marketing specifications. The lack of information on scoping phase led to several iterations on technical specifications between project members.

In the Pro Minute Steam Iron project, the availability of the marketing specifications early in the NPD process helped the technical team to build technical specifications. Clear differences appeared in the coordination of the object sharing, even though the marketing and project leaders knew each other quite well.

> "I consider that technical specifications elaboration is a collective task which involves all project members, so as soon as I have a minimally fulfilled draft, I transfer it to all project members" (Project leader pro minute).

The exchange of information based on marketing specifications was done outside the official IT system for draft and exhibit status but then done in PLM for enabled and validated status. The marketing leader tended to centralize information whereas project manager tended to decentralize the generation of technical specifications through object sharing at the project level as soon as the first draft of technical specifications.

Stylized case

The results of these three projects clearly show cognitive differences between object owners of marketing and technical specifications. Thus, marketing and engineering teams adopt different behaviors for sharing less mature knowledge. Based on observations, the Marketing leader tended to withhold information in order to gain time to decrease market uncertainties before providing marketing constraints to the technical team, whereas the project leader tended to be more open to object sharing early in the NPD process at the project level (Figure 3).

The two coordination modes of knowledge sharing were clearly different for marketing and technical specifications (Figure 3). The marketing leader played a pivotal role and kept tight control on the sharing of marketing specification, whereas the project leader tended to push the draft to all project members in order to receive their feedback as soon as possible in the NPD process. We identified a clear difference in the use of information technologies to support the knowledge maturation between the circles of trust. The

marketing leader tended to use emails in communicating with trusted colleagues and project team members, whereas the project leader tended to use PLM. The behavior concerning the use of IT solutions is quite different with marketing and technical specifications.

Marketing specifications remain in draft or exhibit status longer than technical specifications in scoping NPD phase. Enabled marketing specifications go from project to inter personal circle of trust whereas technical specifications do not have any feedback in more personal circle of trust in our three project observations. For marketing and technical specifications, the project milestone forced object owner to share the object with all project members (Figure 3).

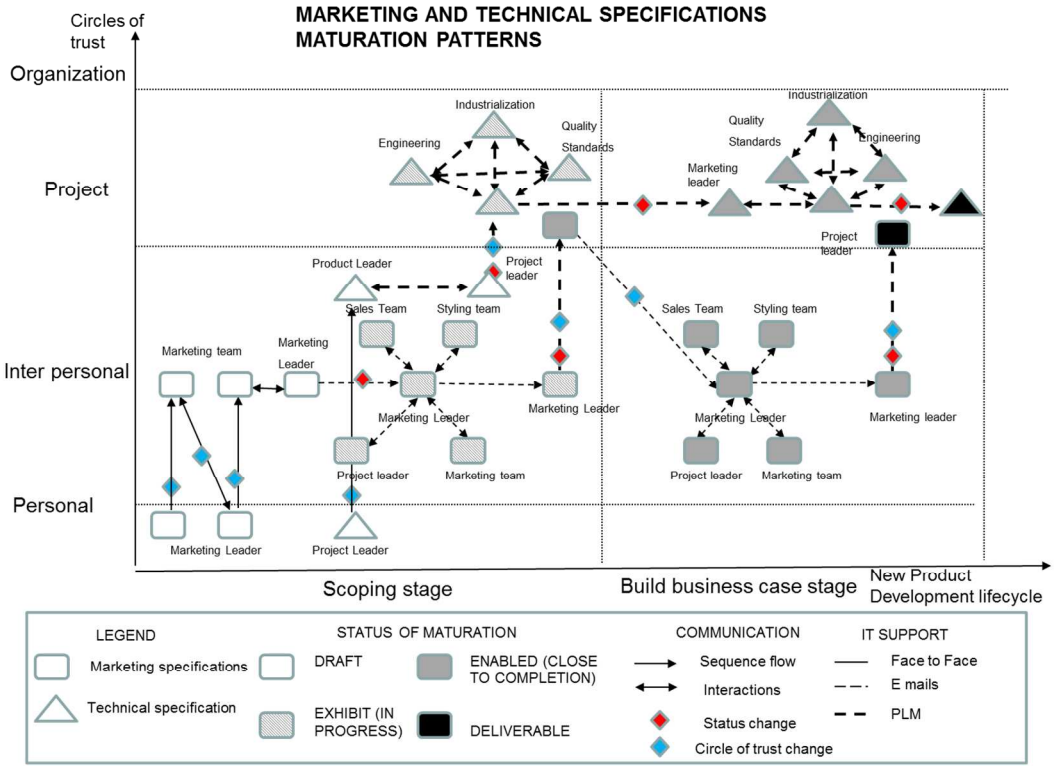

Figure 3: Marketing and Technical specifications maturation patterns (stylized situation)

Discussion

This paper reveals the diversity of knowledge maturation patterns based on 1) types of specifications and functional profiles of project members, 2) psychological safety, and 3) product types. It also points at the limitations of integrated technologies such as PLM to support both knowledge maturation and business operations. Finally, the paper explains and demonstrates how the formal product-development timeline and the knowledge flows across circles of trust affect knowledge maturation.

The diversity in knowledge maturation patterns and psychological safety of project owner

The knowledge maturation process is non linear but rather iterates between circles of trust. During object maturation, project members adapt knowledge sharing with different circles of trust in order to manage the diffusion of objects at the project level, thus creating knowledge asymmetry between project members. The identified feedback from project to inter personal circles of trust could be considered to be counter intuitive in a classical maturation process. Thus, in the three observed projects, marketing leaders were forced to share the marketing specifications at the project level for the stage gate, but they systematically came back to inter personal level just after this gate. The marketing leader respected the project milestone while sharing the marketing specification at the scoping stage gate; however, immediately after, she created a new version of marketing specifications with new elements shared with a limited number of

trusted colleagues. Thus, she developed the completeness and accuracy of the object but with keeping knowledge asymmetry with other project members.

Knowledge sharing difficulties faced during the preliminary phases of object creation are the result of the combination of two key factors: the psychological safety and uncertainty. The psychological safety is associated with the reluctance to share initial ideas before preliminary test of these ideas with trusted colleagues and other project members. The uncertainty is related to the degree of novelty of the knowledge due to the novelty of some knowledge or high changes in the environment during the project. The key challenge was to create a minimal level of confidence between project members to limit the risk of exchanging knowledge too late in the process.
The psychological safety was high between technical project members, which explains the knowledge sharing earlier in the NPD process, whereas it was partial between the marketing and technical teams. This high level of psychological safety was due 1) to co-location issues as the marketing leaders were not in the same place as were the technical teams and 2) to a high turnover in the marketing team in comparison with the technical teams who had known each other for years. Accordingly, marketing leaders had less experience and were less used to working closely with quality or industrialization teams.

Regarding uncertainty, we observed that the marketing teams often shared marketing specification modifications late in the NPD process, and that the number of marketing specification versions was limited in the PLM application. Interviews showed that marketing leaders anticipated that they would have to change their marketing specifications during the preliminary NPD phases because of market evolutions. Therefore, they preferred to give only general marketing specifications and retain details to share as late as possible. If they shared all versions of their detailed specifications with all team members with whom they should, these team members would refuse to take all these versions into account since this would mean doing the same work all over again several times. Thus, marketing preferred communicating detailed specifications late in the process in order to keep degrees of freedom to deal with market uncertainty. The marketing leader was in charge of searching and validating knowledge coming from the market. The average level of volatility was higher in comparison with that of engineering because of the continuous modifications of the market environment. It explains why the marketing leader often wanted to retain knowledge as long as she could in order to make potential modifications or validate some assumptions concerning market trends. In contrast, the average level of volatility of the environment (technical expertise) of the project leaders who belonged to the engineering department was lower. Thus, the typical situation for engineering was to circulate knowledge more readily.

No integrated IT platform supports the whole knowledge maturation process

The analysis of knowledge maturity patterns shows that enterprise systems such as PLM are well suited to support mature knowledge, but only partially support the sharing of immature objects (preliminary versions of marketing specifications). In fact, the marketing leader used face to face, emails or chat in situations characterized early in the NPD process when they did not want to share at the project level. Marketing teams consider that PLM solution does not guarantee that information objects are restricted to a limited number of trusted colleagues. PLM is considered as a project IT solution rather than an interpersonal communication solution. Consequently, this solution is considered as not sufficiently reliable for ensuring confidentiality in object sharing in early stages of product development. Thus, at these early product development stages enterprise systems such as PLM are partially used because it is not easy to create a restricted interpersonal circle of trust to share with trusted resources without taking risks of displaying knowledge to people outside the intended circles of trust. Only few and fragmented solutions are able to manage personal and interpersonal workspaces.

PLM increases information transparency by supporting a workspace for sharing mature objects(Merminod et al. 2012). Storage of objects in a unique database with workflow functionality limits personal political games that can adversely affect knowledge sharing. Because routines are defined for sharing key objects, all involved actors know where to find mature objects and information. For mature objects, enterprise systems such as PLM fare well. Thus, PLM increases knowledge transparency and offers an integrated solution for sharing objects for the whole NPD process. Because organizational routines are defined for sharing objects for milestones (stages), all project members know where to find the latest validated objects. This makes it difficult for actors not to share the minimal knowledge set. In

that sense, PLM brings about semi-structuration effects (Okhuysen et al. 2002). Consistent with Gallivan and Keil's findings in IS development (2003), NPD process structuring is important because it creates a requirement, an expectation that at some milestones, certain knowledge will be shared. It is especially relevant when there is relatively low trust in the team (Staples et al. 2008). Thus, knowledge maturation is linked to IT when IT supports a process – here the stage gate approach for NPD – linked to business operations, a finding consistent with the knowledge management literature (Nevo et al. 2007).

Our exploratory research shows a real challenge in combining inter-individuals with project circles of trust in order to ensure a continuum of object access and tracking exchanges for the project. Thus, object evolution and tracking is difficult with existing IT ecosystem combining structuring and integrated solutions such as PLM for mature objects and flexible solutions for preliminary maturation workspaces.PLM helps implement structuring of knowledge flows through boundary objects and allows actors to anticipate constraints and new needs during product development. Formal interventions (Okhuysen and Eisenhardt, 2002) in the NPD process, such as the use of PLM, are essential for improving NPD knowledge integration. However sequential process development should be viewed only as a first level in the quest to improve the NPD process. We believe this is based on the underlying assumption of PLM systems that the design process is well known, predictable and quite linear. While this is partially true, research (Okhuysen et al. 2002) and our observations indicate that the design process cannot be totally predicted and planned. This is why the contribution of PLM to better integrate knowledge in NPD is valuable but partial, and must be analyzed within the entire social context of product development. As an ecosystem, PLM is all the more fruitful in terms of integration that actors can argue throughout the process and know more precisely when they depart from previous knowledge (Merminod et al. 2012).

PLM is a set of OMS, PRMS and CWS whose joint capabilities are helpful in solving some of knowledge sharing problems. The ecology of capabilities (project structure, validation workflow, visual aid in particular) helps them feel more in control regarding their commitments and the joint capacity to succeed in the development of the product.

Conclusion

In this paper, we introduced the notion of circles of trust to explain how people share immature knowledge and how this very sharing contributes the knowledge maturation. Furthermore, we examined knowledge maturation in the context of NPD, which is a knowledge intensive environment that relies on co-creating and sharing knowledge amongst diverse agents. Rather than examining empirically the entire corpus of organizational knowledge, we tracked proximate process of knowledge maturation that revolved around the work goals defined in the specific stages of the NPD. Thus, we mapped knowledge sharing in circles of trust along two timelines: knowledge maturation, from less mature to mature, and NPD, from conception to a working product. Aligning the two timelines is difficult. On the one hand, the inherent uncertainty in NPD drives the need for knowledge maturation, on the other hand people are reluctant to share information, especially immature knowledge where sharing is most needed, and so people resort to their circles of trust in order to feel psychologically safe. On top of that are various political games that complicate knowledge sharing and hinder knowledge maturation.

This paper reveals the diversity of knowledge maturation patterns based on 1) types of specifications and functional profiles of project members, 2) psychological safety, and 3) product types. It also points at the limitations of integrated technologies such as PLM to support both knowledge maturation and business operations. Finally, the paper explains and demonstrates how the formal product-development timeline and the knowledge flows across circles of trust affect knowledge maturation.

This paper identifies some knowledge maturation patterns in new product development projects depending on knowledge sharing around product lifecycles and circles of trust. Practically, maturity management is a key issue for project coordination, communication facilitation and risk management. In most organizations, preliminary knowledge continues to evolve to its final form (Krishnan et al. 1995) but in some organizations, knowledge never reaches a final state (Boland et al. 1994).The Wheelwright and Clark project typology (radically new products, new product architecture and product renewal) was selected to ensure diversity and rigorousness in projects selection. Even if this paper does not clearly present result differences based on this project typology, preliminary results tend to show that maturation patterns on the two selected objects are different depending on project level of innovativeness. Thus, in

radical new projects, interactions in interpersonal circle of trust are more frequent and last longer than in project renewal configuration. For marketing specifications, the time spent to test marketing specifications within marketing team takes more time in radical projects. For technical specifications, interactions between technical team members are more frequent and intense in radical projects given their complex problem solving related aspects.It would be useful to think about an ecosystem respecting the choice of social actors for validation of intermediary steps while allowing easy travel (Majchrzak et al. 2005), across maturity workspaces, as well as from multiple perspectives and indeterminacy (Majchrzak et al. 2005) that is not allowed by PLM. In fact, our research shows that different digital solutions are used to support the four different maturity workspaces even if organizations would prefer to develop all four workspaces in the same digital application.

This paper can help managers to better understand maturity management pitfalls and so implement a better knowledge sharing strategy for NPD projects. The analysis shows that psychological safety is key dimension to explain the project member behavior in knowledge sharing early in the NPD process. Feedbacks from project to inter personal circles of trust are counter intuitive in a linear maturation process perspective. It would be useful to think about an ecosystem respecting the choice of social actors for validation of intermediary steps while allowing easy travel, across maturity workspaces, as well as from multiple perspectives and indeterminacy. While this paper raises some important issues for knowledge maturation, it also has several limitations. A more in-depth comparison of projects across different industries and project configurations might shed more light on some of our results. We would like to invite more research on cross-cultural NPD that would explore which knowledge sharing mechanisms - depending on knowledge maturity - prevail in cross-cultural relationships when actors share different languages, as well as when other aspects of culture vary.

References

Batenburg, R., Helms, R., and Versendaal, J. *The maturity of product lifecycle management in Dutch organizations: A strategic alignment perspective* Inderscience Enterprises, 2004.

Baxter, R., and Berente, J. "The process of embedding new information technology artifacts into innovative design practices," *Information & Organization* (20:3/4) 2010, pp 133-155.

Berente, N., Baxter, R. J., and Lyytinen, K. "Dynamics of inter-organizational knowledge creation and information technology use across object worlds: the case of an innovative construction project," *Construction Management & Economics* (28:6) 2010, pp 569-588.

Blanco, E., Grebeci, K., and Rieu, D. "A Unified Framework to Manage Information Maturity in Design Process," *International Journal of Product Development* (4:3) 2007, pp 255-279.

Boland, R. J., Tenkasi, R. V., and Te'eni, D. "Designing Information Technology to Support Distributed Cognition " *Organization Science* (5:1) 1994, pp 456-475.

Borgatti, S., and Cross, R. "A Relational View of Information Seeking and Learning in Social Networks," *Management Science* (49:4) 2003, pp 432-445.

Coakes, E. W., Coakes, J. M., and Rosenberg, D. "Co-operative work practices and knowledge sharing issues: A comparison of viewpoints," *International Journal of Information Management* (28:1) 2008, pp 12-25.

Cooper, G. "Perspective: The Stage Gate Idea-to-Launch Process Update, What's New, and NexGen Systems," *Journal of Product Innovation Management* (25:1) 2008, pp 213-232.

Cummings, L. L., and Bromiley, P. "The organizational trust inventory (OTI): developments and validation," in: *Trust in organizations: frontiers of Theory and Research,* R.M. Kramer and T.R. Tylers (eds.), Thousand Oaks, CA, 1996, pp. 302-330.

Dougherty, D. "Organizing practices in services: capturing practice-beed knowledge for innovation," *Strategic Organization* (2:1) 2004, pp 35-64.

Edmondson, A. "Psychological Safety and Learning Behavior in Work Teams," *Administrative Science Quarterly* (44:2) 1999, pp 350-383.

Eisenhardt, K. M., and Graebner, M. "Theory building from cases: opportunities and challenges," *Academy of Management Journal* (50:1) 2007, pp 25-32.

Gallivan, M., and Keil, M. "The user-developer communication process: a critical case study," *Information Systems Journal* (13:1) 2003, pp 37-68.

Grieves, M. *Product Lifecycle Management: Driving the Next Generation of Lean Management* McGraw Hill, 2006.

Hansen, M., Mors, M., and Lovas, B. "Knowledge sharing in organizations: multiple networks, multiple phases," *Academy of Management Journal* (48:5) 2005, pp 776-793.

Kahn, W. "Psychological condigtions of personal engagment and disengagement at work," *Academy of Management Journal* (33:4) 1990, pp 692-724.

Kogut, B., and Zander, U. "What firms do? Coordination, Identity and Learning," *Organization Science* (7:5) 1996, pp 502-518.

Krishnan, V., and Eppinger , S. D. "Accelerating Product Development by Exchange of Preliminary Product Design Information," *Journal of mechanical design* (1:17) 1995, pp 491-498.

Leonard-Barton, D. "A dual methodology for case studies: synergistic use of longitudinal single site with replicated multiple sites," *Organization Science* (1:3) 1990, pp 248-266.

Lewicki, R., McAllister, D., and Bies, R. "Trust and distrust: new relationships and realities " *Academy of Management Review* (23:3) 1998, pp 438-458.

Majchrzak, A., Malhotra, A., and John, R. "Perceived individual collaboration know-how development through information technology enabled contextualization: evidence from distributed teams," *Information Systems Research* (16:1) 2005, pp 9-27.

Mellinger, G. D. "Interpersonal trust as a factor in communication," *Journal of abnormal Social Psychology* (52:1) 1956, pp 304-309.

Menon, T., and Pfeffer, J. "Valuing Internal vs. External Knowledge: Explaining the Preference for Outsiders," *Management Science* (49:4) 2003, pp 497-513.

Merminod, V., and F., R. "How PLM influences knowledge integration in new product development: a set-theoretic approach forc causal analysis," in: *European Conference of Information Systems*, Helsinki, 2011.

Merminod, V., and Rowe, F. "How does PLM technology support knowledge transfer and translation in new product development? Transparency and Boundary Spanners in an international context " *Information & Organization*) 2012.

Merminod, V., Rowe, F., and Watts, S. "Product Lifecycle Management, Knowledge integration and reliability in New Product Co-development: a case study between Europe and China," ICIS, Paris, 2008.

Nevo, D., and Chan, Y. "A delphi study of knowledge management systems: scope and requirements," *Information and Management* (44) 2007, pp 583-597.

Nonaka, I., and Takeuchi, H. *The knowledge creating company: How japanese companies create the dynamics of innovation* Oxford University, 1995.

Okhuysen, G., and Eisenhardt, K. M. "Integrating knowledge in groups: How formal interventions enable flexibility," *Organization Science* (13:4) 2002, pp 370-386.

Pavlou, P. A. and El Sawy, O. (2006). "From IT Leveraging Competence to Competitive Advantage in Turbulent Environments: the Case of New Product Development". *Information Systems Research*, (17:3), pp 198-230.

Sethi, R., and Iqbal, Z. "Stage-gate controls, learning failure, and adverse effect on novel new products," *Journal of Marketing* (72:1) 2008, pp 18-134.

Sheramata, W. A. "Centrifugal and Centripetal Forces in Radical New Product Development Under Time Pressure" *Academy of Management Review* (25:2) 2000, pp 389-408.

Sosa, M., Eppinger, S., Pich, M., McKendrick, D., and Stout, S. "Factors that influence technical communication in distributed product development: an empirical study in the telecommunications industry," *IEEE Transactions on Engineering Management* (49:1) 2002, pp 45-58.

Staples, D., and Webster, J. "Exploring the effects of trust, task interdependence and virtualness on knowledge sharing in teams," *Information Systems Journal* (18:6) 2008, pp 617-640.

Stark, J. "Product Lifecycle Management - 21st century paradigm for product realization,," *Springer, Decision Engineering series, Berlin*) 2004.

Te'eni, D. "Review: A cognitive-affective model of organizational communication for designing IT," *MIS Quarterly* (25:2) 2001, pp 251-312.

Vinck, D., and Blanco, E. *Everyday Engineering: an ethnography of design and innovation* MIT Press, Boston, 2003.

Wheelwright, S., and Clark, K. *Revolutionizing product development* Free Press, NY, 1992.

Winograd, T., and Flores, F. (eds.) *Understanding Computers and Cognition: A New Foundation for Design*, Ablex, Norwood, NJ 1986.

Yin, R. *Case study research: design and methods* Thousand Oaks Sage CA, 2003.